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1922

LABORATORY DIRECTIONS

FOR

GENERAL BIOLOGY

GEORGE A. BAITSELL

General Biology Staff

LORANDE LOSS WOODRUFF
Professor of Biology

GEORGE A. BAITSELL
Assistant Professor of Biology

W. W. SWINGLE
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ALBERT F. HILL
Instructor in Botany

J. WILLIAM BUCHANAN
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New Haven
Osborn Zoological Laboratory
Yale University
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I am impressed with the fact that the greatest thing a human soul ever does in the world is to see something, and tell what it saw in a plain way. Hundreds of people can talk for one who can think, but thousands can think for one who can see. —*Emerson.*

The invention of the microscope made small things seem large, and revealed to sight what was too small to be seen without it; but the use of magnifying glasses brought an advantage with it of a different kind—it taught those who used them to see scientifically and exactly. In arming the eye with these increased powers the attention was concentrated on definite points in the object; what was seen was to some extent indistinct, and always only a small part of the whole object; perception by means of the optic nerve had to be accompanied by conscious and intense reflection, in order to make the object, which is observed in part only with the magnifying glass, clear to the mental eye in all the relations of the parts to one another and to the whole. Thus the eye armed with the microscope became itself a scientific instrument, which no longer hurried lightly over the subject, but was subjected to severe discipline by the mind of the observer and kept to methodical work. The philosopher Christian Wolff observed very truly in 1721, that an object once seen with the microscope can often be distinguished afterwards with the naked eye; and this, which is the experience of every microscopist, is sufficient evidence of the effect of the instrument in educating and training the eye.

—*Sachs.*

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EQUIPMENT.

1. Each student will require the following equipment for his laboratory work:

(a) Provided by the student:

1. Text-books.
2. Loose-leaf notebook, about 8½ x 10¾ inches, with white drawing paper.
3. Dissecting instruments in case, consisting of scalpel, scissors, small forceps, two needles in holders and ruler.
4. Two pencils for drawing—3H and 6H.

(b) Provided by the laboratory:

1. Compound microscope with two eyepieces and two objectives.
2. Dissecting microscope with one lens.
3. Six glass slides.
4. Ten cover glasses.
5. Lens paper for cleaning lenses of microscopes.
6. Filter paper.
7. Cloth for cleaning slides and cover glasses.
8. Pins.

Each student on being assigned a seat in the laboratory should check the list of equipment as given above and see that it is complete.

USE AND CARE OF THE MICROSCOPE.

1. The compound microscope is a delicate, complicated, and expensive instrument and must always be handled with great care. It consists of the following parts:

(a) The **base** and **upright support.**

(b) The **stage,** with a **central opening,** which contains an **iris diaphragm** for regulating the amount of light.

(c) The **mirror,** with concave and plane surfaces, which is attached underneath the stage.

(d) The **body,** with **coarse** and **fine adjustments** for focusing, **draw tube, eyepiece,** or **ocular,** and revolving **nosepiece** holding two **objectives.**

Identify each of these parts and learn how they are used.

2. Each day before using the microscope, see that all parts are clean. Be sure that they are kept clean during the exercise and that the instrument is clean when you leave. If you find the instrument dirty or in bad order, report it at once to the assistant in charge of the room. Lens paper is furnished for cleaning the lenses and it is not permissible under any circumstances to clean the lenses with any other material.

3. Place the microscope in position, with the upright support towards you. See that eyepiece 1 and objective 3 are in position and that the iris diaphragm is open. Adjust the mirror so that the maximum amount of light will be reflected up through the central opening of the stage. In general, use the mirror with the concave surface up.

4. Place the slide, on which the object to be examined is mounted, upon the stage with the object directly over the central opening. Carefully turn the coarse adjustment screw away from you until the top of the objective is approximately one-fourth of an inch from the upper surface of the slide. Then, while looking through the eyepiece, slowly turn the coarse adjustment screw toward you until the object comes into view. Bring the image into an exact focus by slowly turning the fine adjustment screw either to the right or left, as may be necessary. Never focus downward with the coarse adjustment while looking through the microscope. It is less tiring and better in every way to keep both eyes open while looking through the microscope.

USE AND CARE OF THE MICROSCOPE (Continued).

5. Always find an object first with the lowest power (eyepiece 1 and objective 3) as described in the preceding paragraph. Before changing from a lower to a higher power, always see that the object is exactly in the center of the field. The magnification may then be increased as desired in the following ways:

(a) By replacing eyepiece 1 with eyepiece 3.

(b) By replacing objective 3 with objective 7. This is accomplished by revolving the nosepiece. Inasmuch as objective 7 comes to a focus very close to the upper surface of the preparation, it will be necessary to use great care in making this change.

(c) by doing both (a) and (b).

The approximate magnifications afforded by the various combinations are as follows:

Eyepiece 1 × objective 3=50 diameters magnification.
" 3 × " 3=80 " "
" 1 × " 7=300 " "
" 3 × " 7=500 " "

The magnification can be still further increased by extending the draw tube, but this method is rarely used.

When a lower magnification is desired the **dissecting microscope** is used. It gives a magnification of about 10 diameters.

Always use the lowest magnification possible to accomplish the work in hand.

6. At the close of each exercise be sure to remove, from the stage of the microscope, the slide that you have been studying. Examine the microscope carefully and make sure that all parts, including the lenses, are perfectly clean, and then return the microscope to its proper place in the case.

Remember that since there are others who must use the same microscope, the welfare of the laboratory depends upon your coöperation in keeping the apparatus in order.

MICROSCOPIC PREPARATIONS.

7. The objects which will be examined with the compound microscope, may be divided into two classes as follows:

(a) **Permanent mounts,** in which the object to be examined has been previously subjected to complicated histological methods of preparation. Great care must be observed in handling these preparations. A charge will be made for breakage.

(b) **Temporary mounts,** which you will make from time to time from fresh materials according to the following directions:

1. Thoroughly clean a glass slide and cover glass.
2. Place a small drop of water in the center of the glass slide.
3. Place the object to be examined in the drop of water.
4. Cover the drop of water containing the object with the cover glass.
5. Remove any superfluous water remaining around the cover glass with filter paper. Be sure that no water gets onto the upper surface of the cover glass. The preparation is now ready to be studied under the microscope.
6. When you have finished your study of the preparation, clean the slide and cover, and replace them in the drawer for future use.

LABORATORY DRAWINGS.

8. It is essential that careful attention be paid to the following rules for laboratory drawings:

(a) Always **label** every drawing and each of its parts.

(b) Arrange the drawings as neatly and evenly on the page as possible, giving each plenty of space.

(c) Leave at least an inch margin around the edges of the sheet.

(d) Draw only on one side of the paper.

(e) Remember particularly that accuracy and neatness are two of the most important factors in good laboratory work.

(f) See that the laboratory room number, the seat number and your name and class is placed on the upper right hand corner of each sheet of drawings.

PRELIMINARY MICROSCOPIC WORK.

A. Dissecting Microscope.

1. Examine, with the dissecting microscope, a slide on which the printed word YALE has been permanently mounted. What apparent movement results when the slide is moved to the right? To the left? When it is moved toward and away from you? When it is rotated?

B. Compound Microscope.

2. Examine, with the lowest power (eyepiece 1 and objective 3) of the compound microscope, the letter L from the same preparation you have been studying. What apparent movement results when the slide is moved to the right? To the left? When it is moved toward and away from you? When it is rotated? Draw this letter in its apparent position and magnification.

3. Replace eyepiece 1 with eyepiece 3. Draw.

4. Replace eyepiece 3 with eyepiece 1 and, by revolving the nosepiece, replace objective 3 with objective 7. Carefully refocus with fine adjustment. Draw.

5. Replace eyepiece 1 with eyepiece 3. Draw.

6. Note that the magnification can be still further increased by extending the draw tube. Extend it to its full length and, after refocusing, note the effect on the magnification.

7. Examine (eyepiece 1 and objective 7) a preparation of scales from the wing of a butterfly. Make several outline drawings showing different types of scales.

8. Replace eyepiece 1 with eyepiece 3. Study the markings on the surface of the scales and make a drawing of a small portion of a scale to show their character.

PROTOPLASMIC MOVEMENT.

1. Mount two or three young leaves from near the tip of a stem of Elodea. Examine under the low power and draw a portion of one leaf to show the general structure.

2. Examine the preparation with the high power and find an area in which the cells show a movement of their contents. Carefully study the nature of the movement. Does the substance move in the same direction in all the cells? Does it change its direction after a time? Do any of the green, disc-shaped bodies **(chloroplastids)** pass through the walls between adjacent cells? What is their course? Draw several adjacent cells and indicate by arrows the direction of the movement observed.

3. Stain the preparation with iodine solution. Make a large drawing of a cell to show **cell wall, cytoplasm, nucleus, chloroplastids** and **vacuole.**

4. Examine a few filaments of Oscillatoria under the high power, and make a diagram to illustrate the nature of the movement observed.

5. Observe the movements shown on the stimulation of the Sensitive Plant (Mimosa).

6. Place a small piece of a Clam's gill on a slide and, with two needles, gently tease it apart in a drop of the body fluid. Cover and examine with high power. Note the currents in the surrounding fluid caused by the rapid vibration of the delicate, protoplasmic processes **(cilia)** which are present on the outer, exposed surface of certain cells **(ciliated cells)** of the gills.

7. To demonstrate the fact that lifeless particles may also exhibit motion, examine, with the high power, a drop of water which contains a little powdered carmine. The motion observed is termed **Brownian movement.**

AMOEBA.

1. Mount and examine (oc. 3 x obj. 3) a drop of water which contains Amoebae. These will be noted as very small, irregular, semi-transparent, granular bodies. When one is found, be careful not to move the slide so as to lose the specimen. Note: (1) the method by which the animal moves; (2) the constant but slow changes in the shape of the body, and (3) the irregular processes **(pseudopodia)** which are formed.

2. Distinguish the transparent, outer layer of protoplasm **(ectoplasm)** from the inner, granular layer **(endoplasm)**. In this connection, examine particularly the pseudopodia.

3. Make at least 10 outline drawings, at 1-minute intervals, showing changes in the shape of the organism. Indicate in each drawing the anterior and posterior end of the animal.

4. Note the food materials in process of digestion. They are contained in **food vacuoles.** If carefully watched it is sometimes possible to observe the manner in which an Amoeba ingests food and discharges the indigestible refuse.

5. Locate the transparent, spherical **contractile vacuole** and note that the fluid contents are discharged at intervals. Find the transparent, disc-shaped **nucleus.**

6. Make a drawing (2 or 3 inches in diameter) of an animal to show all of the details of structure which you have observed in your preparation.

PLANT STRUCTURE.

1. Carefully peel off with a scalpel, a portion of the delicate, transparent covering **(epidermis)** from the upper surface of a leaf, and make a temporary mount. Examine, with the low power of the microscope, and draw about ten adjacent **epidermal cells** to show their structure and arrangement. Each cell should be about half an inch in diameter.

2. Examine, with the low power, a permanent preparation of stained sections of an **Onion root.** Note that some of the sections are cut transversely, and that others are cut longitudinally.

3. Study first a tranverse section. Note the faintly stained, granular substance **(cytoplasm)** which surrounds the **nucleus** of each cell and fills the greater part of the space within the **cell wall.** Note the **vacuole** present in some of the cells.

4. Draw about 10 adjacent cells to show their structure and arrangement. Each cell should be about half an inch in diameter.

5. Draw, under the high power, a single cell about an inch in diameter, showing **cell wall, cytoplasm, nucleus,** and **vacuole.**

6. Study a longitudinal section and make a similar drawing of a cell from near the tip of the root.

7. Compare the last two drawings of the cell and from them make an outline, in perspective, of a single cell which will show the three dimensions.

ANIMAL STRUCTURE.

1. Mount a small piece of shed Frog skin **(epidermis),** which has previously been stained with eosin water. Examine, with both the low and the high power, and draw about 10 adjacent cells to show their structure and arrangement.

2. With the handle of the scalpel, or the end of your finger, **gently** scrape the inside of your cheek. Mount the scrapings in a drop of water on a clean slide and examine with both the low and the high power. Draw, under high power, several cells of different shapes.

3. Stain the cells by adding a drop of acetic carmine. Examine under the high power and observe the changes which have taken place. It will be noted that the nucleus stains more heavily. Make a drawing, about an inch in diameter, of a single cell, showing the appearance of the **cytoplasm** and **nucleus.**

4. Examine a permanent preparation of the liver of an animal and draw several of the cells as seen under the high power. Note particularly the cell walls.

5. Make a temporary mount of a drop of Frog's blood which has been diluted with normal salt solution. Study under the low power and note the appearance of the disc-shaped cells **(red corpuscles)** floating in the plasma.

6. Examine the preparation with the high power, gently tapping the cover glass from time to time in order to set the cells in motion so that you may see their three dimensions. Draw three or four cells as seen from various aspects.

SPIROGYRA.

1. Mount a few filaments of Spirogyra and examine with the low and the high power. Draw a portion of one of the filaments to show its division into cells.

2. Study under the high power. Note the cell walls and the connection between adjacent cells. Note also in each cell the long, band-like, green **chloroplastids.** Count them and make out their arrangement.

3. Stain the preparation with a small drop of iodine solution. Note the changes of color in the rounded bodies imbedded in the chloroplastids. These are the reserve food bodies **(pyrenoids),** and their blue color after the treatment with iodine indicates the presence of starch.

4. Examine the cell wall carefully and note the thin layer of **cytoplasm,** which lines it internally, and the large **vacuole,** filled with cell sap, which occupies the greater part of the cell. Focus carefully near the center of the cell and find the **nucleus,** surrounded by a thin layer of the cytoplasm, and suspended by delicate strands of cytoplasm which run out to the layer of cytoplasm lining the cell wall.

5. Make a drawing about two inches in length of a single cell, showing the detailed structure and the connection with adjacent cells.

6. **Asexual reproduction:** Examine a number of filaments carefully for evidence of recent multiplication by transverse division of some of the cells. Draw.

7. **Sexual reproduction:** Examine a permanent preparation which shows the filaments in process of **conjugation.** Study with high power and draw as many stages in the process of conjugation as can be found, including the fully formed **zygotes.**

EUGLENA.

1. Mount a drop of water which contains Euglena, and examine with the low power. The active specimens will be seen as green, elongated, free-swimming bodies. When an individual is not actively swimming, it shows certain characteristic squirming movements which result in marked changes **(euglenoid changes)** in the shape of the cell.

2. Make a series of outline drawings to show the successive euglenoid changes in the shape of a single individual.

3. Study the preparation with the high power. Distinguish the **anterior** and **posterior ends.** Note: (1) the **flagellum** which is attached in a depression **(gullet)** at the anterior end (careful focusing will be necessary); (2) the red pigment spot **(stigma)**; (3) the **contractile vacuoles** and **reservoir**; (4) the **nucleus.**

4. The green color of Euglena is due to **chlorophyll.** It is present in a number of oval disks **(chloroplastids)** which are suspended in the protoplasm. Other larger bodies **(pyrenoids)** also can be noted which retain the food material **(paramylum)** after it has been manufactured.

5. Make a drawing about 3 inches long showing all the observed structures.

6. Occasionally, inactive individuals are found which have become almost spherical in shape and which are surrounded by a rather thick **cyst** wall. Such specimens are **encysted.** They may undergo **division** during encystment. Study any encysted specimens present in your preparation and make drawings to show the structure as observed.

VOLVOX.

1. Place a drop of water containing Volvox on a slide. Examine, without cover glass, under the low power. Each Volvox colony will be seen as a more or less transparent, hollow sphere. Note that each colony is composed of a large number of tiny, greenish, flagellated cells **(somatic cells)** which are imbedded in a transparent, gelatinous material. In many cases a number of darker colored spheres **(daughter colonies)** are enclosed within the walls of the parent colony. The daughter colonies have arisen by repeated divisions of specialized germ cells **(parthenogonidia)**, which develop without fertilization. Make an enlarged drawing of a Volvox colony to show the structure as observed.

2. Carefully place a cover glass on the preparation and examine with the high power. Focus on the wall of a colony at the equator, so as to get a profile view of the cells in this region. Make a careful study of a number of the somatic cells and note that the cell body of each consists of an irregular-shaped, greenish bit of cytoplasm. Branching out from each cell body are very fine cytoplasmic strands which run through the intercellular material and connect with other cell bodies so that there is a protoplasmic continuity among the cells of the colony. Each cell possesses two flagella which project to the exterior. Draw a portion of the wall of the colony giving a profile view of the cells as outlined above.

3. Focus on one of the asexual daughter colonies. Note the comparatively small amount of intercellular material between the cells. Draw a portion of the wall of the colony.

4. Study a Volvox colony in which sexual cells are present. In such a colony note a **spermary**, which consists of a large number of male cells, or **sperm (microgametes)**, grouped together to form a rather flat plate, and an **ovary** of about the same size as the spermary, but which contains only a single female cell, or **egg (macrogamete)**. Both the spermaries and ovaries are imbedded in the wall of the colony and arise from specialized cells. Draw to show the structure as observed.

PARAMECIUM.

1. Mount a drop of water which contains Paramecia, together with a little powdered carmine, and examine with the low power. The Paramecia will be seen as light colored, rapidly moving bodies which rotate on their long axis as they swim. With the naked eye, the Paramecia are just barely visible as minute white specks.

2. Select a quiet animal under the low power and then study with the high power. It will probably be necessary to remove the cover glass and add a drop or two of quince seed jelly to the preparation in order to quiet them. Distinguish the **anterior** and **posterior** ends. Note: (1) the thin, clear, outer layer **(ectoplasm)** of the body; (2) the granular, inner layer **(endoplasm)**; (3) the fine, vibratile, hair-like organs **(cilia)** which cover the entire body; (4) the depression **(oral groove)** which begins at the anterior end and extends obliquely backward near the middle of the body; (5) the **mouth** which is located near the posterior end of the oral groove; (6) the funnel-like depression **(gullet)** which leads from the mouth down into the endoplasm; (7) the position and rhythmic appearance and disappearance of the two **contractile vacuoles** with their radiating canals. Focus carefully on the edge of the body and note (8) the minute, oval, regularly arranged bodies **(trichocysts)** lying in the ectoplasm just beneath (9) the outer surface **(pellicle)**.

3. Observe that the current caused by the ciliary action sweeps the carmine particles, which were placed in the drop of water, down the oral groove through the mouth opening and into the gullet, at the lower end of which they collect into **food vacuoles**. Note the numerous food vacuoles in the endoplasm.

4. Make a drawing about 3 inches long showing the structures observed.

5. Remove the cover glass of the preparation you have been studying and add a drop or two of acetic carmine. This will kill the animals and also stain the nuclear structures **(macronucleus** and **micronucleus)**. Study with the high power and add the details of nuclear structure to your drawing in paragraph 4.

6. Place a drop of the water containing Paramecia on a clean slide and kill the animals by adding a drop or two of iodine solution. Note what happens to the cilia and trichocysts. Make a drawing of a small portion of the ectoplasm showing some of the trichocysts with the **stinging hairs** protruded.

7. Make a fresh preparation of the Paramecia and draw any animals you see which may be in a state of **division** or of **conjugation.**

VORTICELLA.

1. Mount a drop of water which contains Vorticellae, together with a little powdered carmine, and examine with the low power. Make a drawing of a small group of the animals attached to a piece of debris.

2. Study the preparation, with the high power, and note that the general shape of the organism is that of an inverted bell, usually attached by means of a long contractile **stalk.** Note the outer **pellicle,** the **ectoplasm,** and the **endoplasm.** Determine how and where the particles of carmine are taken into the body and identify the **food vacuoles** with the carmine particles.

3. Identify the following structures: (1) the **peristome,** or rounded rim, about the mouth of the bell; (2) the **disk,** or elevated, plate-like area, included within the peristome; (3) the **vestibule,** or depression, between the disk and the peristome; (4) the **gullet,** or slender canal, leading from the vestibule, through the mouth opening, toward the center of the body, and (5) the **contractile vacuole.** Determine what parts of the body bear cilia. Study the contractions of the stalk.

4. Make a drawing about 2 inches long showing the general structure of the organism and as many as possible of the details mentioned above.

5. Add a little acetic carmine to your preparation, which will kill and stain the animals, and then note: (1) the long, U-shaped **macronucleus;** (2) the small, rounded **micronucleus;** (3) that the stalk consists of a sheath continuous with the pellicle of the bell, and surrounding (4) the central contractile filament **(myoneme).** Add these structures to your previous drawing.

BACTERIA.

1. Mount a drop of stagnant water which contains decaying organic material. Study the preparation carefully, with the high power, and note the various types of Bacteria which are there present. The straight, rod-like forms are **Bacilli**; the bent, rod-like forms are **Spirilla**; the extremely small, spherical forms are **Cocci**, and the very long filamentous forms filled with tiny, yellow sulfur granules are **Beggiatoa**. Note the movement which each kind of Bacteria exhibits. Compare with Brownian movement. Make a drawing of the field under observation.

2. Mount a little of the substance secured from between your teeth. Study the preparation under the high power and identify the various forms of Bacteria which you find in it.

3. Make a temporary mount of a drop of water in which a piece of meat has been decomposing. Study the preparation under high power and identify the various forms of Bacteria which you find in it.

4. Examine, under the high power, the series of permanent preparations of various kinds of Bacteria, and draw a few cells of each kind.

YEAST.

1. Examine a flask of water in which have been placed some compressed Yeast and sugar. Note the physical characters of the fluid, including the smell, color and taste, and the minute bubbles of gas (carbon dioxide) which are continually rising to the surface.

2. Mount a drop of the scum and examine with the low and the high power. Note the **Yeast cells** with the **starch grains** interspersed among them. Under the high power, make a drawing of the field under observation.

3. Make a series of drawings to show the asexual reproduction of the Yeast cells by **budding.** Draw a large **colony** of the Yeast cells. How many cells are there in a yeast plant?

4. Treat the preparation with iodine solution. The starch grains are stained a deep blue and the Yeast cells, brown. Make a large drawing to show the **structure** of a Yeast cell, noting **cell wall, cytoplasm,** large **central vacuole,** and **oil globules.** The nuclear material cannot be distinguished in the yeast cells except by special methods of staining.

MOLD.

1. Examine the fungus growth on a piece of moldy bread and note its general appearance.

2. Place a very small piece of bread, which bears the Mold, in a drop of water on a slide and tease it apart with dissecting needles, cover and examine with the low power. Note that the bread mold is composed of a network of filaments, or **hyphae.** The hyphae taken together constitute the **mycelium.**

3. Identify the following forms of hyphae: (1) the relatively thick **stoloniferous hyphae** which ramify through the substance of the bread; (2) the groups of short **root-like hyphae;** (3) the **erect hyphae,** each of which bears at its apex a **sporangium** containing great numbers of tiny, brown **spores.** Draw a portion of the plant which shows all these parts.

4. Make four drawings of **sporangia,** in different stages of development, ending with the stage at which the spores have been discharged. Draw also a few of the **spores.**

MOSS.

1. In this plant the sexual generation **(gametophyte)** consists of a short, upright stem which bears leaves, arranged in spirals, and fine, root-like structures **(rhizoids).**

2. The asexual generation **(sporophyte)** is a dependent structure which develops from a fertilized egg, near the tip of the gametophyte to which it remains attached. The sporophyte consists of a **foot,** which is attached to the gametophyte; (2) a **stalk,** and (3) a highly developed sporangium **(capsule)** filled with spores.

3. Examine a specimen of the Moss plant which shows the sporophyte with the gametophyte attached to it. Identify the structures mentioned above and make a drawing to show them.

4. Open the capsule of the sporophyte and note that it contains the tiny, brown **spores.** Mount a few of these, study their structure under the high power and make a drawing of two or three of them.

5. Study, with the low power, a prepared slide on which has been mounted the tip of a gametophyte to show the sexual organs situated there. Note: (1) the larger, club-shaped male organs **(antheridia)** which contain great numbers of **sperm cells;** (2) the slender, female organs **(archegonia)** with enlarged basal portions, each of which contains a single **egg cell;** (3) the numerous rod-like structures **(sterile hairs)** which are found interspersed among the reproductive sexual organs. Make a drawing to show the structures observed.

FERN.

1. In this plant the sexual generation **(gametophyte)** consists of a very small, green, independent, leaf-like structure known as a **prothallus.**

2. The asexual generation **(sporophyte)** is the large, leafy fern plant, and it shows a differentiation into **root, stem** and **leaf.**

Asexual.

3. The stem of the Fern sporophyte **(rhizome)** grows underground. It bears the leaves, which grow upward, and the roots, which grow downward. The portion of the plant above ground consists of the leaf stalk, and the leaf proper **(lamina).** Each leaf is subdivided into a number of lobes **(pinnae),** and these are further subdivided, in some species, into leaflets **(pinnules).**

4. Examine the leaves and note that they are of two kinds: (1) sterile leaves **(foliage),** and (2) fertile leaves **(sporophylls)** on the under surface of which the spores are developed in the brownish-colored bodies **(sori).** The sori are partly covered by flap-like outgrowths **(indusia)** of the surface of the leaf.

5. Make (1) a drawing of the upper surface of a foliage pinna which shows the **venation,** and (2) of the under surface of a sporophyll pinna to show the sori.

6. Scrape off a few of the sori and place them in a drop of water on a slide. Tease them apart with dissecting needles, cover and examine under the low power. Note that they contain numerous spore cases **(sporangia),** which are filled with the minute brown **spores.** Note also the manner in which the sporangia open to discharge the spores. Make a drawing to show the structures observed.

Sexual.

7. Study a permanent mount of a prothallus, first, with a dissecting microscope, and then with the low power of a compound microscope. Note: (1) the root-like structures **(rhizoids)** by which it is attached to the soil; (2) the male sexual organs **(antheridia)** which occur near the base among the rhizoids; (3) the female sexual organs **(archegonia)** which occur near the **apical notch** at the anterior end. Make a drawing of the under surface showing the structures observed.

8. Examine a preparation which shows the manner in which the young sporophyte develops from the archegonium of the prothallus after fertilization has occurred.

SEED AND SEEDLING.

A. The Bean (Dicotyledon—Ex-albuminous).

1. Examine a Bean seed which has been soaked in water overnight. Note the scar **(hilum)**, which marks the place of attachment to the parent plant, and, at one end of the hilum, the tiny opening, or **micropyle.** Draw.

2. Remove the outer covering **(seed coat)**, thus exposing the two, white, thick seed leaves, or **cotyledons,** which are attached to, and form a part of, the small, rod-like embryo proper. One end of the embryo **(radicle)** is somewhat pointed, and this becomes the root. The other end, which lies between the cotyledons, is the primary bud **(plumule)** of the shoot and bears two tiny leaves. The portion of the embryo between the radicle and plumule is the **hypocotyl.** Draw to show the structures observed.

3. Examine and draw a bean seed, which has begun to germinate, and a series of seedlings from one to three weeks old. Note particularly in each stage: (1) the change in shape, color, and position of the cotyledons; (2) the development of the shoot, consisting of the stem, with **nodes** and **internodes,** and the leaves, and (3) the development of the **primary root** and its branches, or **secondary roots.**

B. The Corn (Monocotyledon—Albuminous).

4. Examine a Corn seed which has been soaked in water overnight. Note that the embryonic area is to be seen as a white portion on one side, and near the small end of the seed. With a sharp scalpel cut the seed in half, in a longitudinal plane, passing through the center of the embryonic area. Study the cut surface of one of the halves under the dissecting microscope. Note: (1) that the greater portion of the seed is filled with the food material **(endosperm)**, which shows a differentiation into the hard endosperm and the soft endosperm; (2) that the small embryo, which lies to one side, is in contact with the soft endosperm by the single, atypical cotyledon, or **scutellum,** and (3) that the main growing region of the embryo, as in the Bean, consists of the hypocotyl with the plumule at the upper end and the radicle pointing down. Draw to show the structures observed.

5. Examine and draw a germinating Corn seed and a series of seedlings as in paragraph 3.

ROOT.

1. Place a small Radish seedling on a slide and examine it with the dissecting microscope. Note particularly the root with the definite area of root hairs. Draw the entire seedling.

2. With a sharp scalpel, carefully cut off the root at a point just above the root hairs and make a temporary mount of it. Be sure that sufficient water is placed under the cover glass so that the piece of root is entirely surrounded. Examine the preparation under the low power. Note the **root hairs, growing point,** and **root cap.** Make a drawing to show these structures.

3. Stain the preparation you have been studying with a drop of iodine. This treatment should differentiate the cytoplasm and nuclei of the root hair cells. If found, add them to your drawing in paragraph 2.

4. Secure a transverse section through the root hair zone of a young Corn root, mount and examine the preparation under the low power. Note: (1) in the center of the section the compact, circular central cylinder **(stele)**; (2) lying next to this, a second cylinder **(cortex)** composed of several layers of larger cells, and (3) the outer cylinder **(epidermis)** composed of a single layer of elongated cells, many of which show a definite prolongation of the outer wall to form a root hair. Make a drawing to show the structure as observed.

STEM.

1. Examine, with the low and with the high power, a permanent mount of a transverse section of the stem of Aristolochia. Note that it is composed of three cylinders, namely:

I. An outer cylinder **(epidermis)** consisting of a single layer of rectangular cells with thickened outer edges.

II. A middle cylinder **(cortex)**, which is divided into (1) a strengthening layer next to the epidermis, and (2) the chlorophyll-bearing **chlorenchyma.** The cells of the innermost layer of the chlorenchyma are larger, contain starch, and comprise the **starch sheath.**

III. The highly differentiated central cylinder **(stele)** consists on the outside of (1) several layers of cells with thickened walls, which form a ring of strengthening tissue just interior to the chlorenchyma of the cortex; (2) the **fibro-vascular bundles,** composed of the inner **xylem** portion, with large ducts, and the outer **phloem** portion. The xylem and phloem are separated by the actively growing cells of the **cambium,** which also forms a ring of tissue around the stem and connects the vascular bundles, and, finally, (3) the **pith,** comprising undifferentiated cells which occupy a considerable area in the center of the stem.

Draw the entire section in outline and then carefully fill in a quadrant to show the structure as observed.

2. Examine a piece of the young stem of an Oak which has been sawed so as to show a transverse, longitudinal, and tangential section. Identify and make a drawing to show the following structures: (1) the **bark**; (2) the **cambium ring**; (3) **rings of annual growth**; (4) **medullary rays,** and (5) **pith.**

BUD.

1. Examine, with the low power, a stained and mounted median longitudinal section of the typical **summer bud** of Elodea. Note that it consists of (1) the central stalk **(rudimentary stem)**, and, branching off from it, (2) the **rudimentary leaves** in various stages of development. The diameter of the rudimentary stem is larger in the older portions of the bud and it gradually decreases until it terminates in (3) the **growing point**, which is composed of rapidly-dividing, embryonic cells **(meristem** tissue).

2. Note that the leaves develop in regular order, the youngest leaves being nearest the growing point. In the early stage they consist of only a few cells and form small mounds on the surface of the stem. The older leaves overarch the growing point and form a protection for it. Make a drawing to show all structures observed.

3. Examine, with the naked eye and also with the dissecting microscope, the typical **winter bud** of the Lilac. It consists of the same parts as the naked bud of Elodea, but, for protection during the winter, the outer leaves of the bud **(scale leaves)** are differentiated from the inner leaves **(foliage leaves)**. Make a slightly enlarged drawing of the bud to show the external structure.

4. Remove the leaves of the bud, both scale and foliage, and arrange them in regular order. Note the transition from the scale leaf to foliage leaf. Make a series of drawings to show the transition between the two types as observed.

5. Take another Lilac bud and cut a transverse section of it. Examine, with the dissecting microscope, and note the arrangement **(vernation)** of the young leaves in the bud. Draw to show the structure observed.

LEAF.

1. Examine a leaf of a **monocotyledonous** plant (e.g., Corn). Note the medium longitudinal **midrib** and the parallel **veins.** Make a drawing of the upper surface.

2. Examine a leaf of a **dicotyledonous** plant (e.g., Rose). Note: (1) the leaf stalk **(petiole)**; (2) the leaf blade **(lamina)** with (3) the medium **midrib** and net-like arrangement of the **veins.** Make a drawing of the upper surface.

3. With the point of a scalpel remove a small portion of the outer covering **(epidermis)** from the under surface of a leaf. Mount in a drop of water and study with the low power. Note: (1) the epidermal cells and among them (2) the openings in the leaf **(stomata)** through which the interchange of gases takes place. Each stoma is enclosed by (3) two specialized epidermal cells **(guard cells).** Make a drawing of the epidermis to show the structures observed.

4. Examine, with the low power, a stained and mounted transverse section of a Rose leaf. Select a portion of the leaf to one side of the midrib and study with high power. Note: (1) the upper layer of large, irregularly shaped cells **(upper epidermis),** below which can be seen two rows of (2) smaller cells **(palisade cells)** which are placed with their long axes at right angles to the upper epidermis. Below these is (3) an area in which the cells are not so definitely arranged **(spongy parenchyma)** and in which (4) intercellular spaces **(lacunae)** are present. The lacunae open to the exterior through the stomata. The palisade cells and the spongy parenchyma together comprise (5) the **chlorenchyma.** The cells of the chlorenchyma contain (6) the chlorophyll-bearing bodies **(chloroplastids).** (7) The **vascular tissue** of the veins appears, in transverse section, as more or less circular groups of irregular, lightly stained cells imbedded in the spongy parenchyma. (8) The under surface of the leaf is covered with a layer of epidermal cells **(lower epidermis)** similar to the upper surface, but more stomata are present. Make a drawing of the section to show the structures observed.

FLOWER.

1. Examine the flower provided and note that it is composed of **whorls** of modified leaves attached to a slightly differentiated portion **(receptacle)** of the stalk as follows: (1) The outermost whorl **(calyx)** consists of a number of leaf-like structures **(sepals).** The sepals form the outer covering of a flower bud. They are frequently green in color and the basal portions are often united to form a tube. (2) The next whorl **(corolla)** consists of **petals.** These may be of various colors and in some flowers are also united to form a tube. The calyx and corolla together constitute the **accessory** parts of the flower as distinguished from the **essential** parts which they enclose. These latter consist of (3) a whorl of **stamens** and (4) the central structure **(pistil)** of the flower. Make an enlarged drawing of a longitudinal section of the flower to show the relations of the parts as observed.

2. Carefully detach one of the stamens, place it on a slide and study with the dissecting microscope. Note that it consists of (1) a stalk **(filament),** and (2) head **(anther)** which contains (3) the tiny **pollen grains,** or **microspores.** Make a drawing to show the structure as observed.

3. Place some of the pollen grains on a slide and study them with the compound microscope. Draw.

4. Make a microscopic preparation of some pollen grains which have germinated and formed the pollen tube **(male gametophyte).** Study under the high power and make a drawing.

5. Remove the calyx, corolla and stamens. Examine the pistil with the dissecting microscope. Note that it consists of (1) an enlarged basal portion **(ovule case)** from which projects (2) a stalk **(style).** The style terminates in (3) an enlarged portion **(stigma)** which secretes a sticky substance to which the pollen adheres. Draw to show the structures observed.

6. Cut a transverse section of the ovule case. Place on a slide and examine with the dissecting microscope. Make a drawing to show the cavities containing the immature seeds **(developed ovules)** and their attachment to the **placenta.**

FRUIT.

1. With the scalpel cut a partially developed Apple in half transversely. Place the cut surface of the flower end on a slide and examine the remains of the flower with the dissecting microscope. The flower originally had five sepals, five petals, ten stamens and five carpels. See how many of these you can find. Note that the fruity portion of the apple, which is the typical condition in this class of fruits, is developing from the enlarged receptacle at the tip of the stem. Make a drawing from the flower end to show the general structure.

2. Cut a mature Apple exactly in half longitudinally. Examine a cut surface. Note that the flesh is divided into a larger outer portion, which develops from the walls of the receptacle, and a smaller inner portion, constituting the core and containing the seeds, which develops from the walls of the ovule case. Make a drawing of a cut surface to show the general relations.

3. Take out one or two of the seeds, noting their attachment at one end to the placenta. Remove the hard outer seed coat. Note that the seed is the dicotyledonous type like that of the Bean.

HYDRA.

1. Examine, with the dissecting microscope, a living Hydra in a watch glass containing water. Observe the animal both when expanded and when contracted. Touch the expanded animal with a dissecting needle and observe what happens.

2. Examine the animal in the watch glass as before, with the low power of the compound microscope. Note (1) the **body**, which resembles an elastic tube, and is attached at one end by (2) the **foot.** (3) At the opposite end **(hypostome)** there is (4) a central opening **(mouth)**, which is surrounded by (5) a circlet of **tentacles.** Note the number of tentacles your specimen possesses and compare with others at your table.

3. Focus on the cellular body wall and note that it is composed of (1) the outer layer **(ectoderm)** and (2) an inner layer **(endoderm)** which surrounds (3) a large central cavity **(enteric cavity)**, into which the mouth opens. Focus on one of the tentacles and note that it is composed of ectoderm and endoderm, and also that the enteric cavity continues throughout its length. Note the batteries of stinging cells **(nematocysts)** imbedded in the ectoderm of the tentacles.

4. Hydra commonly reproduces asexually by budding. Examine your specimen and see if any **buds** are present. At certain seasons of the year it also reproduces sexually. At such times the male gonads **(testes)**, which produce the sperm, develop as swellings in the body wall just below the tentacles and the female gonads **(ovaries)**, which produce the eggs, develop below the testes.

5. Make (1) a careful drawing of an expanded animal, showing in detail all parts observed above, and (2) an outline drawing of a contracted animal.

6. Examine, with the low and with the high power, a permanent preparation of a transverse section through the body of a Hydra. Note: (1) the outer layer of ectoderm and (2) the inner layer of endoderm, both of which are composed of a great number of cells, and are separated from each other by (3) a thin, non-cellular layer **(mesogloea)**. These layers surround (4) the enteric cavity. Draw the section as observed.

OBELIA (1).

Asexual.

1. Examine, with the dissecting microscope, a specimen of Obelia which has been stained and mounted. Note the general form of the colony.

2. Study the preparation with the low power of the compound microscope. Note: (1) the upright stem **(hydrocaulus)** with the side branches, each of which bears either (2) a hydra-like nutritive zooid **(hydranth)** or (3) a club-shaped reproductive zooid **(gonangium).** The stem is composed of (4) an inner, deeply staining portion **(coenosarc),** which is a continuation of the same material in each zooid, and (5) an outer, transparent skeletal sheath **(perisarc)** which encloses all parts of the colony. Note that the perisarc expands into (6) a cup-shaped structure **(hydrotheca)** surrounding each hydranth and into (7) a longer, urn-shaped structure **(gonotheca)** which encloses each gonangium. Observe the constrictions in the perisarc below each zooid.

3. Study a hydranth and note: (1) the body wall composed of an outer layer of ectoderm and an inner layer of endoderm, both of which are continuous with the coenosarc in the stem; (2) the central cavity **(enteric cavity),** and (3) the tentacles which surround (4) the mouth.

4. Study a gonangium and note that the club-shaped stalk **(blastostyle)** which, as in a hydranth, is continuous with the coenosarc, bears the asexual **medusa buds.** Note the opening at the tip of the gonotheca through which the mature medusa buds escape as free living forms.

5. Make a half page drawing of an Obelia colony showing the structures observed.

OBELIA (2).

Sexual.

1. Examine with the naked eye, in a watch glass containing water, a preserved medusa of the Obelia type (e.g., Gonionemus). Note the gelatinous consistency of the body and the umbrella, or bell shape. The upper, convex surface is called the **aboral,** or **exumbrella,** and the lower, concave surface is called the **oral,** or **subumbrella.**

2. Study the specimen, with a dissecting microscope, from the oral surface. Note: (1) the **tentacles** attached near the periphery, each with an adhesive pad near its tip; (2) the perforated, circular diaphragm **(velum)** attached below the tentacles; (3) the central structure **(manubrium)** suspended from the top of the bell and made up of (4) the wide-lipped **mouth,** which opens into (5) the **enteric cavity.** Radiating from the base of the manubrium are (6) the four **radial canals** bearing (7) the reproductive glands **(gonads).** The radial canals run to the periphery of the disk where they connect with (8) the **circular canal,** which runs around the periphery near where the tentacles are attached. Note also (9) the **sense organs,** which are located around the margin of the bell at the base of each tentacle, and also between the bases of some of the tentacles.

3. Make (1) a drawing of the specimen from the oral surface and also (2) from the side to show the structures observed.

EXTERNAL ANATOMY OF THE EARTHWORM.

1. Examine a preserved Earthworm and note the long, tubular body made up of a considerable number of segments **(metameres)**. Count the segments of your specimen and compare the number with others at your table. Note: (1) the **mouth,** which is situated at the anterior end of the body below the projecting lobe **(prostomium)**, and (2) the **anus** situated at the posterior end of the body, where it can be seen as a vertical slit in the last segment; (3) the swollen region **(clitellum)** lying in the region between segments 28 and 35.

2. With one hand take hold of the anterior end of the Earthworm and draw the body through the fingers of your other hand. The rough feeling is due to the presence of bristles **(setae)** which project through the body wall. Ascertain the arrangement of the setae and the number present on each segment.

3. Examine your specimen with the dissecting microscope and find the following openings: (1) openings of the **sperm ducts** in the swellings on the ventral surface of segment 15; (2) openings of the **oviducts** just lateral to the inner double row of setae in segment 14; (3) openings of the **seminal receptacles** in the grooves between segments 9 and 10, and 10 and 11, on a line with the outermost row of setae; (4) openings of the **nephridia** just lateral and anterior to the setae of the inner row on either side of each segment; (5) the openings **(dorsal pores)** on the anterior end of each segment in the median line.

4. Make (1) a drawing, twice natural size, of the anterior forty segments of the body from the ventral surface, and (2) a drawing, at the same magnification, of the posterior ten segments of the body from the dorsal surface to show the structure as observed.

INTERNAL ANATOMY OF THE EARTHWORM.

1. Place an Earthworm, dorsal surface up, in a dissecting pan and fasten it with one pin through the **prostomium,** at the anterior end of the body, and another through the posterior end of the body. With fine scissors cut very carefully through the body wall, in the median dorsal line, a few segments posterior to the **clitellum.** Extend the cut through the anterior end of the animal, being careful to cut just through the body wall so as not to injure the intestine just below. Beginning at the posterior end of the cut, spread the cut edges, carefully cutting away the segmental partitions **(septa),** which attach the body wall to the alimentary canal, and fasten the cut edges to the parafine with pins.

2. Examine the specimen and note: (1) the rather thick **body wall** consisting for the most part of muscular tissue; (2) the body cavity **(coelom),** which is divided into a linear series of chambers by the septa; (3) the **alimentary canal** running the length of the body, through the coelom, as a straight tube, and (4) the **dorsal blood vessel,** generally full of coagulated blood, which runs along the top of the alimentary canal. It gives off (a) small segmental branches, which run to the body wall and alimentary canal, and (b) at the anterior end, in segments 7 to 11, five pairs of contractile, thick-walled vessels **(aortic loops,** or **arches),** which pass around the digestive tract and unite below with the **ventral blood vessel.**

3. Examine the alimentary canal and note that it consists of the following parts: (1) the **mouth,** which opens just below the overhanging prostomium; (2) the thick, muscular **pharynx,** extending back to segment 6, and attached to body wall by many fine muscles; (3) the thin-walled **oesophagus,** largely obscured by (4) the overlying **reproductive organs,** extending between segments 7 and 14; (5) the **crop,** at about segment 14; (6) the thick-walled, muscular **gizzard,** at about segment 18; (7) the **intestine,** extending from the gizzard to (8) the **anus** at the extreme posterior end of the body.

4. Make a drawing, twice natural size, to show these structures as observed, being careful that each organ is drawn correctly with reference to the segments.

NERVOUS SYSTEM OF THE EARTHWORM.

1. Fasten your dissected specimen as before in a dissecting pan. Make a transverse cut through the alimentary canal a few segments posterior to the gizzard. Move the cut ends slightly to one side and find the **nerve cord** lying directly below in the median line. Carefully remove the alimentary canal, anterior to the cut just made, as far as the pharynx. In doing so, cut all the septa so as not to disturb the nerve cord. Trace the latter to the anterior end of the pharynx, where it divides to form the **nerve collar** which encircles the pharynx. Note the bilobed swelling **(cerebral ganglion)** on the dorsal surface of the nerve collar, which constitutes the brain of the animal.

2. Examine the exposed portion of the nerve cord, with the dissecting microscope, and note that it expands in each segment to form a **ganglion**, from which two pairs of nerves arise. A smaller pair of nerves arises, in each segment, anterior to the ganglion. Make an enlarged drawing of the first 15 segments of the body, showing the nerve cord *in situ*.

BODY PLAN OF THE EARTHWORM.

3. Examine, with the low power, a permanent preparation of a transverse section through the body of an Earthworm. Draw the section in outline (four inches in diameter) and then fill in a quadrant to show the general structure as follows:

I. **Body Wall**, which consists of: (1) a thin, transparent outer membrane **(cuticle)**; (2) a layer of elongated, epidermal cells **(epidermis)**; (3) a layer of **circular muscles** and (4) a thicker layer of **longitudinal muscles**, which together comprise most of the body wall, and (5) a very thin layer of cells **(peritoneal epithelium)** lining the coelom.

II. **Alimentary Canal**, which appears in a transverse section as a ring of tissue with a dorsal thickening and infolding **(typhlosole)**. The wall of the canal consists of (1) an outer layer of rounded gland cells **(chloragogue layer)**, which also fill the cavity of the typhlosole; (2) a muscular layer with both circular and longitudinal fibers; (3) a vascular layer with many tiny blood vessels, and (4) a layer of ciliated, elongated cells **(lining epithelium)**, which form the inner lining of the tract, and are the essential agents in the digestion and absorption of food. A section through the dorsal and through the ventral blood vessels can be noted, lying above and below the digestive tract respectively.

III. **Nerve Cord**, which consists of two distinct structures, the outer envelope, or **sheath**, and the inner nervous portion. The sheath is made up of an outer epithelial layer which encloses a thicker muscular layer. Imbedded in the muscular layer, dorsally, are the three **giant fibers** which run the length of the cord, and, ventrally, the **subneural** blood vessel. The nervous portion of the cord within the sheath is bilobed and contains nerve cells and fibers. If the section happens to be through the region of a ganglion a pair of the lateral nerves may be seen.

EXTERNAL ANATOMY OF THE CRAYFISH (1).

1. Examine a preserved Crayfish and note that the body, which is entirely covered with a chitinous **exoskeleton**, consists of a rigid anterior portion **(cephalothorax)** and a jointed, flexible, posterior portion **(abdomen)**.

2. A study of the appendages shows that the cephalothorax consists of thirteen segments, of which five constitute the head and eight constitute the thorax. Note the indentation **(cervical groove)** in the exoskeleton of the cephalothorax which marks the division line between the head and thorax. The exoskeleton of the cephalothorax is known as the **carapace**, and it is extended anteriorly to form the **rostrum**. Note the short **antennules**, the long **antennae** with the opening of a green-gland **(nephridium)** on the basal joint of each, the stalked **eyes**, and the ventral **mouth** concealed by appendages.

3. The abdomen consists of six segments and ends in a posterior median extension **(telson)**. Note the anal opening on the ventral surface of the telson. Examine the abdominal segments and note how they are attached together so as to permit movement. Attached to each of the abdominal segments is a pair of typical, biramous appendages **(swimmerets)**. In the male, the first two pairs of abdominal appendages are modified and enlarged for the transfer of sperm. In the female, the first pair is greatly reduced. Determine the sex of your specimen.

4. Examine the exoskeleton of a detached, abdominal segment and note: (1) the dorsal, arched portion **(tergum)**; (2) the ventral, calcified bar **(sternum)** with the soft, membranous cuticle, which permits movement, and (3) the downwardly projecting, lateral portions **(pleura)**. Examine the paired, biramous appendages, or swimmerets, and note: (4) the basal, attached portion **(protopodite)** which bears (5) two jointed branches **(exopodite** and **endopodite)**.

5. Make (1) a drawing of the entire animal from the left side, and (2) a drawing of the abdominal segment from the **end.**

EXTERNAL ANATOMY OF THE CRAYFISH (2).

1. Carefully cut off the lateral part of the carapace from the left side of your specimen, thus exposing the gill chamber containing the gills, and then lay the animal on its right side under water. Note the feathery character of the gills and their attachment either to the appendages, or to membranes present at the base of the appendages. Find the modified, paddle-shaped portion **(scaphognathite)** of the second maxilla, which lies in the anterior end of the gill chamber and, by its movements, keeps a current of water flowing through, and out the anterior opening.

2. Carefully examine and identify all of the appendages, using your text-book. Then, beginning at the posterior end of the body, carefully remove all the appendages one by one from the left side of the animal, and pin each one in a dissecting pan in the proper order and corresponding position. In removing them, be sure to get the whole of each appendage, including the gills when present. The small appendages around the mouth must be handled very carefully with fine forceps.

3. Study and make a drawing of the following appendages: (1) **antenna**; (2) **second maxilla**; (3) **third maxilliped**; (4) **first** and **second walking legs**, and (5) **third** and **sixth abdominal.** Identify and label the homologous parts in each.

EXTERNAL ANATOMY OF THE HONEY BEE (1).

1. Examine a freshly killed Honey Bee of the worker type and note that the body is divided into **head, thorax** and **abdomen.** Study the specimen with the dissecting microscope. On the head note the jointed feelers **(antennae),** which project from the anterior surface, the large **compound eyes,** and the **mouth parts.** Observe that the thorax is composed of three segments, each of which bears a pair of jointed legs. The second and third thoracic segments also bear a pair of wings. Observe that the abdomen, like that of the Crayfish, is composed of six segments. The exoskeleton of each of these segments is made up of a dorsal plate **(tergum)** and a ventral plate **(sternum).** At the posterior end of the abdomen is the sting, the anus, and the opening for the sexual organs. Make an enlarged drawing of the specimen from the left side to show the structures observed.

2. Remove the head, place it on a slide, and study the anterior surface under the dissecting microscope. Note: (1) the large, compound eyes, which project from either side of the head; (2) the small, simple eyes **(ocelli)** in the center and almost on top of the head; (3) the pair of jointed antennae, and just below them on the anterior surface, (4) a median, dome-shaped structure **(clypeus),** to which is attached (5) the upper lip **(labrum).** As seen from the anterior surface the chief mouth parts consist of (6) a long, median tongue **(ligula);** (7) a pair of **labial palps,** one on each side of the tongue; (8) a pair of wider, projecting maxillae, lateral to the palps, and (9) a pair of **mandibles,** attached one near either end of the labrum. The mandibles are generally closed, and when they are they obscure the underlying labrum. Make an enlarged drawing of the head from the anterior surface to show the structures observed.

EXTERNAL ANATOMY OF THE HONEY BEE (2).

1. With fine forces, carefully remove the left **prothoracic leg,** being sure that you secure all the joints. Mount and examine it with the dissecting microscope and also with the low power of the compound microscope. Note that it is composed of five joints which, beginning with the one attached to the body, are designated as follows: (1) **coxa;** (2) **trochanter;** (3) **femur;** (4) **tibia,** and (5) the five-jointed **tarsus.** Note: (6) the feathery **branched hairs** for gathering pollen, which are present on all the joints except the tarsus; (7) the **pollen brush,** and (8) the flattened spine **(velum)** on the tibia; (9) the circular **antenna comb** on the first joint of the tarsus, which works in connection with the velum on the tibia to form an **antenna cleaner;** (10) the **eye brush,** also on the first joint of the tarsus, and (11) the **foot,** or terminal portion of the tarsus, which consists of a fleshy pad **(pulvillus)** and a pair of notched claws. Draw to show the structures observed.

2. Remove, mount, and study as before, the left **mesothoracic leg.** Observe the **spur** on the tibia, which is used to clean the wings, and also to pry out the pollen from the pollen basket on the metathoracic legs. Draw a portion of the leg to show this structure.

3. Remove, mount, and study as before, one of the **metathoracic legs.** Note: (1) the **pollen basket,** which is a concavity on the outer surface of the tibia; (2) the **wax pincers,** which consist of a row of spines **(pecten)** on the end of the tibia and a smooth, concave plate **(auricle)** on the first joint of the tarsus, and (3) the **pollen combs,** also on the first joint of the tarsus. Draw a portion of the leg to show these structures.

4. With fine forceps, remove the last two segments of the abdomen. Place them on a slide under the dissecting microscope, and, with a pair of needles, dissect out the sting. Note the following parts: (1) a pair of **barbed darts,** which with the sheath form a long, rigid, median structure; (2) a pair of fleshy **sting feelers,** one on either side of the darts, and (3) the **poison sac** with attached **poison glands.** Draw to show the structures observed.

LIFE HISTORY OF A MOTH.

1. The life cycle of the Moths, and other insects with complete metamorphosis, consists of four stages, namely, **egg, larva, pupa,** and **adult.**

I. **Egg.** The eggs of a moth are generally laid on, and attached to, leaves, which later serve as food to the embryos. Examine, with the dissecting microscope, a preparation of a leaf with the attached eggs and make a drawing.

II. **Larva.** Examine the segmented, worm-like, larval stage **(caterpillar)** of the moth and make a drawing to show the following structures: (1) the head, which appears as one segment and bears on its anterior surface tiny, simple eyes **(ocelli)** and, ventrally on each side of the mouth, a pair of jaws **(mandibles);** (2) the **thorax,** consisting of the next three segments, each bearing a pair of small legs with sharp hooks, and (3) the **abdomen,** consisting of the posterior nine segments, some of which also possess appendages, known as **false legs.** Note the openings **(spiracles)** of the tracheal tubes on each side of certain **segments.** Draw the animal from the left side to show the structures observed.

III. **Pupa.** Examine the silk **cocoon,** which the animal spins and encloses itself at the close of the larval period. Carefully open the cocoon, remove the living pupa, and examine under the dissecting microscope. Identify the **head, thorax, abdomen, antenna cases, wing cases,** and **leg cases.** Make a drawing of (1) the cocoon, and (2) the pupa from the ventral surface.

IV. **Adult.** Examine a mounted adult moth from the dorsal surface. Identify (1) the **head,** with **eyes** and **antennae;** (2) the **thorax,** with **fore** and **hind wings** and **legs,** and (3) the segmented **abdomen.** Make a drawing of the dorsal surface, showing all structures possible.

CLAM.

1. The shell of a Clam consists of right and left halves **(valves)**, which are hinged together along the dorsal surface. Concentric lines of growth are visible on the shell, and it, also, can be noted that these radiate from the anterior end **(umbo)** of the shell. Draw the external surface of the left valve.

2. Carefully remove the left valve from your specimen, noting the structure of the **hinge**, and the attachments of the **anterior** and the **posterior adductor muscles** to the interior of the shell. It is necessary to cut both of these before removing the valve. Note that the internal organs are enclosed by a membranous **mantle** which lines both valves of the shell. The space between the two halves of the mantle, in which the organs lie, is known as the **mantle cavity.** Turn back the left half of the mantle, cutting a little at each end, and thus expose the structures in the mantle cavity as follows: (1) the large dorsal **visceral mass**, from which projects (2) the ventral muscular **foot**; (3) the pair of delicate, striated **gills**, and (4), at the posterior end of the mantle, the dorsal **(exhalent)** and the ventral **(inhalent) siphon tubes.**

3. Below the anterior adductor muscle, note the two pairs of **palps**, between which the **mouth** may be found. At the posterior end of the body find the **anus**, which opens into the exhalent siphon, dorsal and slightly posterior to the posterior adductor muscle. Trace the intestine anteriorly from the anus to the **heart**, which lies in a median dorsal position, enclosed in the delicate **pericardial sac.** The heart consists of a single **ventricle**, through which the intestine passes, and two delicate, thin-walled **auricles** lying laterally and below and also attached to the pericardial sac. The auricles are apt to be destroyed in the dissection.

4. Make an enlarged drawing showing the internal structure of the clam as observed.

EXTERNAL ANATOMY OF THE FROG.

1. Examine a chloroformed Frog and note: (1) the general form; (2) the division into head and trunk; (3) the fore and hind limbs; (4) the opening of the cloaca; (5) the character of the skin, and (6) the difference in color between the dorsal and ventral surfaces.

2. Examine the head and note the following structures: (1) the large mouth; (2) the pair of small, external openings, or nostrils **(external nares)**; (3) the pair of circular ear drums **(tympanic membranes)**; (4) the protruding eyes, and (5) the tiny nodule **(brow spot)** in the skin between the eyes. Note how the eyelids close over the eyes and how they may be withdrawn into a cavity in the skull and thus protected from injury.

3. Examine the fore limb and identify the upper arm, forearm, and hand; the latter with wrist and digits. Examine the hind limb and identify the thigh, shank and foot; the latter with ankle, digits, and interdigital web. Note the difference in length between the two limbs.

4. Make a drawing of the extended animal, from the dorsal surface, showing as many of the above characters as possible.

BUCCAL CAVITY OF THE FROG.

5. Pin the Frog in a dissecting pan, with the ventral surface up. Pull back the lower jaw, cutting a little at each corner so as to expose fully the mouth, or buccal, cavity, and then pin the lower jaw to the ventral surface of the body. Note the upper jaw with (1) a projecting, fleshy upper lip, and bearing (2) numerous, very fine teeth **(maxillary teeth)**, which you can feel by rubbing over them with your finger; (3) the two larger **vomerine** teeth on the dorsal roof of the mouth; (4) the internal nostrils **(internal nares)**, one on either side of the vomerine teeth; (5) the openings of the **Eustachian tubes**, posterior to the internal nares. Note the lower jaw with (6) the muscular **tongue**, which is attached anteriorly, and (7) the circular elevation **(glottis)** with a median, slit-like opening into the tube to the lungs. Leading from the posterior end of the mouth is the oesophagus, which runs to the stomach. Make a drawing of the mouth cavity to show the structures observed.

VISCERA OF THE FROG.

1. Pin out a freshly chloroformed Frog, with the ventral surface up, in a dissecting tray. With fine forceps lift up the loose skin near the posterior end of the abdomen, and then with scissors make a longitudinal incision just to one side of the median line through the skin only, running from the posterior end of the abdomen **(pelvic region)** to the throat. Make a transverse incision in the skin in the pelvic region, and also just posterior to the fore limbs. Pin out the flaps of skin.

2. In the same way make a longitudinal cut through the muscle tissue of the body wall, running from the pelvic region to the **sternum.** Cut through the bony shoulder girdle on each side of the sternum, being careful not to injure the underlying heart. Make transverse cuts as before and pin the flap of body wall on each side, over the flaps of skin previously pinned out.

3. Examine the large body cavity, or coelom, filled with the viscera, which you have now exposed. It is lined with a delicate membrane **(peritoneum)**, which is continuous over each of the organs in the body cavity, and which forms folds **(mesenteries)** by which these organs are suspended and held in place. Identify and study the following organs:

I. The **heart,** at the anterior end of the coelom enclosed in a delicate, transparent sac **(pericardium)** containing the pericardial fluid. Carefully remove the pericardium. Watch the pulsations of the heart and determine the number per minute. Place your finger tip on the heart while it is beating, and note the alternate tension and relaxation. Identify (1) the single, thick-walled **ventricle,** which is posterior in position; (2) the pair of thin-walled **auricles,** anterior to the ventricle, and somewhat obscured by (3) a large blood vessel **(conus arteriosus)**, which leads from the ventricle. Lift the heart and locate, underneath, the **sinus venosus,** which opens into the right auricle.

II. The **lungs,** consisting of a pair of thin-walled vascular sacs which communicate to the exterior by the trachea and glottis. The lungs lie close to the body wall on each side, dorsal and posterior to the heart.

III. The **liver,** consisting of three, large brownish-colored lobes, which lie in a very prominent position posterior to the heart. Push the lobes apart and find (1) the **gall bladder,** which receives the bile from each of the lobes. Leading from the gall bladder is (2) the bile duct, which, after receiving a duct from (3) the elongated, yellowish **pancreas,** opens into the small intestine.

IV. **The alimentary canal,** consisting of a closed tube running from the mouth to the anus. Identify (1) the enlarged **stomach,** which lies to the animal's left, just under the tips of lobes of the liver, and (2) the oesophagus, which can be traced as an undifferentiated tube from the anterior end of the stomach to the mouth. (3) Posteriorly the stomach opens through (4) a constriction **(pyloric valve)** into (5) the **small intestine,** and, at the posterior end of the body cavity, the small intestine enlarges to form (6) the large intestine, or **rectum,** which merges into (7) the **cloaca.** Note the small, dark, spherical **spleen** lying near the anterior end of the rectum.

4. Arrange the organs so that they show to the best advantage, and make a full page drawing to show as many as possible of the observed structures.

RESPIRATORY ORGANS AND ALIMENTARY CANAL OF THE FROG.

1. Secure the specimen which you dissected the last time and pin it, ventral surface up, in the dissecting pan. Entirely remove the skin from the ventral surface anterior to the forelimbs. Carefully cut the attached blood vessels and remove the heart from the body. Locate the pair of lungs and trace each one to the common, thin-walled **larynx,** which lies just ventral to the glottis, previously noted in the study of the buccal cavity.

2. With the scissors, make a median ventral cut through the wall of each lung and continue the cuts to the larynx. Make a longitudinal median cut through the ventral wall of the larynx, connecting posteriorly with the cut from each lung. Pin back the walls of the lungs and larynx, thus exposing the interior. Note: (1) the structure of the lungs; (2) the relation of the larynx to the glottis, and (3) the pair of elastic **vocal cords** lying on each side of the larynx. Make a drawing to show the structures as observed.

3. Cut off and discard the portion of the lower jaw which lies anterior to the glottis. Next cut through the mucous membrane lining the dorsal roof of the mouth cavity, just posterior to the openings of the Eustachian tubes. Be careful not to disturb the bony structures of the upper jaw. You have now freed the anterior end of the oesophagus from the body. With your forceps, lift up the portion of the lower jaw, with the attached oesophagus, and carefully cut all the mesenteries which attach the alimentary canal to the body. Make a transverse cut through the anterior end of the rectum. Now remove the entire alimentary canal, together with the attached lungs, liver, and pancreas, from the body, taking care not to disturb the underlying organs. Pin out the alimentary canal in the dissecting pan. Identify oesophagus, stomach, pyloric valve, small intestine, large intestine or rectum. Make an outline drawing of the entire structure.

4. Examine, with the low and the high power, a permanent preparation of Frog intestine (transverse section). Note: (1) the thin, outer covering **(peritoneum)**; (2) the muscular layers consisting of an outer longitudinal layer and an inner, thicker circular layer; (3) the connective tissue layer **(submucosa),** and (4) the epithelial layer **(mucosa),** which is thrown into folds, and forms the inner lining of the intestine. The mucosa consists of two types of elongated epithelial cells, one the **ab-absorptive cells** and the other the **secretive cells,** or unicellular glands, which may be distinguished by the presence of a large oval vacuole in each. Draw the section in outline and fill in a sector to show the observed structures.

HEART.

1. Examine a Pig's heart and note that it is conical in form, with a broad base and a narrow apex. Place it with the apex pointing toward you and note the following external features: (1) the **left ventricle,** with very thick, muscular walls, continuing to the tip of the apex; (2) the **right ventricle,** with thinner walls, lying beside the left ventricle; (3) the **left auricle,** and (4) the **right auricle,** both lying anterior to, and forming the base of, the ventricles. The auricles have much thinner walls than the ventricles, and are each provided with (5) an ear-like flap of tissue **(auricular appendage).**

2. Explore the cavity of the left auricle, noting (1) the openings of the **pulmonary veins,** and (2) the opening into the left ventricle.

3. Explore the cavity of the left ventricle, noting (1) the very heavy, muscular walls; (2) the **mitral valve,** guarding the opening from the auricle, the edges of which are attached to (3) elevations **(papillary muscles)** of the muscular walls of the ventricle by a number of (4) fine tendinous cords **(chordae tendineae).** Feel with your finger and find (5) the opening into the **aorta.** Study the aorta, noting (6) its thick heavy walls; (7) the **semilunar valves,** and (8) the opening of the **coronary artery** just beyond the valves.

4. Explore the cavity of the right auricle, noting (1) the large opening from the **venae cavae;** (2) the small opening of the **coronary vein** just posterior to the former, and (3) the opening into the right ventricle.

5. Explore the cavity of the right ventricle, noting (1) the thinness of the walls as compared with the left ventricle; (2) the **tricuspid valve,** which shows the same structure as the mitral valve. Find the opening into (3) the **pulmonary artery,** which contains (4) semilunar valves the same as the aorta.

6. Make a drawing of the heart from the left side, showing as many as possible of the observed structures.

UROGENITAL SYSTEM OF THE FROG.

1. Pin the specimen, from which you have previously removed the alimentary canal and associated organs, in a dissecting pan, ventral surface up as before. Carefully cut through the bony pelvis in the median line and thus expose the extreme posterior portion **(cloaca)** of the alimentary canal, into which the ducts from the urinary and genital organs empty, and to the ventral surface of which the thin-walled, bilobed **bladder** is attached.

2. **Female Frog.** In the spring the right and left ovaries become greatly distended and fill a large portion of the body cavity. Separate the ovaries and push them to either side so that the other organs may be seen to advantage. Note: (1) a pair of reddish, flattened, oval-shaped **kidneys (mesonephros)** close to the dorsal body wall; (2) a pair of elongated, orange-colored **adrenal bodies,** one lying on the ventral surface of each kidney; (3) a pair of yellowish **fat bodies** with long finger-like processes; (4) a pair of long, coiled **oviducts** which open anteriorly into the body cavity near the base of each lung. Posteriorly, before the opening into the cloaca, each of the oviducts becomes differentiated into (5) a thin-walled **uterus.** Examine the outer margin of the kidneys and find (6) the **ureters,** which can be traced posteriorly to their openings into the cloaca. Note also the blood vessels attached to the kidneys. Make an enlarged drawing to show the structures observed.

3. **Male Frog.** Locate and examine the following parts of the male urogenital system: (1) a pair of reddish, flattened, oval-shaped **kidneys (mesonephros),** close to the dorsal body wall; (2) a pair of white **testes** attached to the kidneys by a number of fine ducts **(vasa efferentia);** (3) a pair of elongated, orange-colored **adrenal bodies,** one lying on the ventral surface of each kidney; (4) a pair of yellowish **fat bodies** with long finger-like processes; (5) in many specimens a pair of much-coiled **rudimentary oviducts** are to be found situated laterally to the kidneys. Examine the outer margin of the kidneys and find (6) the **urogenital canals,** which can be traced posteriorly to their openings in the cloaca. Note also the blood vessels attached to the kidneys. Make an enlarged drawing to show the structures observed.

KIDNEY.

1. Examine a half of a Pig's kidney **(metanephros)**. Observe that it is somewhat bean-shaped in outline, with a marked depression **(hilus)** on one edge, where the ureter is connected. Examine the cut surface of your specimen and note that three regions in the kidney can be distinguished as follows: (1) an outer, darker area **(cortex)** containing great numbers of the microscopic, nephridial elements **(Malpighian bodies)**; (2) an inner, striated medullary portion **(medulla)**, containing the **uniferous tubules**, and (3) the **pelvis**, which is really the expanded end of the ureter. The uniferous tubules of the medulla open into the pelvis at the tips of the conical-shaped projections **(pyramids of Malpighi)**, and the latter are separated from each other by prolongations of the cortex into the pelvis. Make a drawing of the cut surface of the half kidney to show the structure as observed.

2. Examine, with the low and the high power, a permanent preparation of a section of frog kidney **(mesonephros)** and note the general arrangement, consisting of a comparatively thin area on one side, containing a number of definite, rounded bodies (Malpighian bodies), and a thicker area, filled with the **uriniferous tubules**, which have been sectioned in various planes. Make a drawing to show the general arrangement.

3. Select a single Malpighian body and focus on it with high power. It consists of (1) a spherical knot of fine blood vessels **(glomerulus)** containing numerous red blood corpuscles, which appear yellow in the preparation, and (2) a definite, surrounding membrane **(Bowman's capsule)**, which is essentially the enlarged end of a uriniferous tubule. Focus on a portion of one of the uriniferous tubules and note the cellular wall and central lumen. Make a drawing of a Malpighian body and of a portion of a uriniferous tubule.

SPINAL NERVES OF THE FROG.

1. Pin your specimen in the dissecting pan as before. Remove any of the viscera which may be present in body cavity. Examine the dorsal wall of the body cavity and note the paired **spinal nerves**, which may be seen as small, white cords running laterally from either side of the spinal cord. They arise in the spinal cord and emerge from between the vertebrae through the light colored **calcareous bodies.**

2. Beginning at the anterior end, identify and trace the ten pairs of spinal nerves as follows:

I. A small pair, which emerge from between the first and second vertebrae just anterior to the fore limbs, usually giving off a small branch to the second nerve before continuing laterally into the muscles.

II. A large pair, which supply the fore limbs after having usually received branches from the first and third pairs. This union of the first, second and third nerves is known as the **brachial plexus.**

III. A small pair, which, after giving off a branch to the second pair, can be traced laterally into the muscles.

IV, V, and VI are small pairs, which can be traced into the muscles of the body wall.

VII, VIII, and IX are larger pairs which run almost directly posteriorly and anastomose to form the **sciatic plexus,** from which arises the large **sciatic** nerve. By careful dissection, follow the sciatic nerve from the plexus down through the leg and into the foot, noting the various branches which are given off. Note also a branch of the seventh nerve, which is given off anterior to the sciatic plexus.

X. A small pair, which emerge from the openings near the anterior end of the **urostyle** and supply chiefly the urogenital organs.

3. Make a drawing to show the location and course of the spinal nerves.

CENTRAL NERVOUS SYSTEM OF THE FROG (1).

1. Take your dissected specimen and carefully remove the skin from all parts of the body. The fore, and hind limbs may also be cut off and discarded if desired. Fasten the specimen, dorsal surface up, in a dissecting pan, and then, with a sharp, pointed scalpel, pick off, bit by bit, the bony roof of the skull in the region between the eyes, using great care not to injure the brain underneath by inserting the scalpel too deeply. Small pieces of the bone may also be snipped off with the tips of the scissors. Continue the area of dissection anteriorly to the nasal region and posteriorly to the end of the skull, thus entirely exposing the brain. Note that it is covered by a thin pigmented membrane **(dura mater)**, which should be carefully removed with fine forceps.

2. Examine the brain from the dorsal surface, and, beginning at the anterior end, note the following parts: (1) the fused **olfactory lobes**, from which the **olfactory nerves** may be seen extending anteriorly to the nasal region; (2) the pair of **cerebral hemispheres** which merge anteriorly into the olfactory lobes; (3) an unpaired portion **(diencephalon)** bearing (4) a small, median structure **(pineal gland)**; (5) a pair of egg-shaped **optic lobes**, back of which is (6) a transverse ridge of tissue **(cerebellum)**, and, finally, posterior to the cerebellum, (7) an enlarged anterior portion of the spinal cord, which constitutes the **medulla oblongata.** It contains (8) a triangular depression, the **fourth ventricle.** The **fore-brain** consists of the olfactory lobes, cerebral hemispheres, and diencephalon; the **mid-brain**, as seen from the dorsal surface, of the optic lobes, and the **hind-brain** of the cerebellum and medulla oblongata.

3. Make a drawing at least twice natural size to show the dorsal surface of the brain *in situ.*

CENTRAL NERVOUS SYSTEM OF THE FROG (2).

1. Continue the dissection of the central nervous system by very carefully removing, with the tips of the scissors, the bony, dorsal arches of the vertebrae, thus exposing the **spinal cord** throughout its entire length.

2. Next remove the entire brain and spinal cord from the animal. In order to do this it will be necessary to cut the cranial and spinal nerves, which run from the central nervous system to the various regions of the body. Begin at the anterior end and cut the olfactory nerves first. Then carefully raise the anterior end of the brain, note the large optic nerves on the ventral surface anterior to the optic lobes, and cut them. Continue posteriorly in this manner, and when the brain and spinal cord are entirely free, remove and place in a small dish of water for further study.

3. Study the ventral surface of the brain under the dissecting microscope and locate the region of the fore-brain, mid-brain, and hind-brain. Note: (1) the origin of the olfactory nerves; (2) the origin of the optic nerves and the crossing of the fibers of each in the mid-ventral line under the optic lobes, to form (3) the **optic chiasma**; (4) the heart-shaped **infundibulum**, which lies underneath the optic chiasma, and (5) the **pituitary body**, which lies in a median position posterior to the infundibulum. The pituitary body frequently is detached from the brain when removing the latter from the body.

4. In the spinal cord note: (1) the enlargement in the brachial region where the nerve supply of the fore-limb arises; (2) the enlargement in the pelvic region where the nerve supply of the hind-limb arises, and (3) the small terminal portion **(filum terminale)**.

5. Make a drawing of the ventral surface of the brain and spinal cord at least twice natural size, showing all of the structures observed.

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SHEEP'S BRAIN.

1. Examine the dorsal surface of a Sheep's brain. Note that the large anterior portion **(cerebrum)** consists of a right and left **cerebral hemisphere,** posterior to which is the median, unpaired **cerebellum.** The latter lies above the medulla, containing the **fourth ventricle,** which merges into the **spinal cord.** The brain is enclosed in three membranes: (1) the **dura mater,** which lines the interior of the skull; (2) the **arachnoid,** which is the membrane you see, and (3) the **pia mater,** which lies below the arachnoid, and is very closely applied to the brain tissue. Note that the outer portion of the cerebrum **(cerebral cortex)** is arranged in folds **(gyri),** between which are depressions **(sulci)** of varying depths.

2. Examine the ventral surface of your specimen. Note: (1) the **cerebral hemispheres;** (2) the **olfactory lobes** (often destroyed in removing the brain from the skull), from each of which (3) an **olfactory** nerve runs posteriorly; (5) **optic chiasma,** from which (6) the **optic nerves** arise; (7) the median **infundibulum,** under and posterior to the optic chiasma, and lying on (8) the thickened, ventral wall **(crura cerebri)** of the mid-brain; (9) the prominent, transverse band of fibers **(pons variolii)** with (10) a root of the important fifth cranial nerve **(trigeminal)** arising just posterior and on each side; (11) the eighth cranial nerves **(auditory),** which arise close to the ventral edge of the cerebellum just posterior to the fifth.

3. Examine the cut surface of a half of a brain which has been sectioned in a median longitudinal plane. Note the general arrangement with the large fore-brain, or cerebrum, which lies anterior and dorsal to the mid-brain. Identify the following structures in addition to those noted above: (1) the **corpus callosum,** which consists of a fibrous plate connecting the two cerebral hemispheres; (2) the **corpora quadrigemina,** which lie just anterior to the cerebellum and constitute the dorsal wall of the mid-brain; (3) the small **pineal gland,** lying in an indentation anterior to the corpora quadrigemina, and (4) the cavity **(fourth ventricle)** in the medulla, lying underneath the cerebellum.

4. Make a drawing of the half-brain from the cut surface, showing as many as possible of the structures which you have found in the preceding paragraphs.

HISTOLOGY OF NERVE TISSUE.

1. Examine, with the low and with the high power, a permanent preparation of a transverse section through the spinal cord of a Frog. Note: (1) the thin, outer covering **(dura mater)**; (2) the rather shallow indentation on the dorsal side **(dorsal fissure)**; (3) the deeper indentation on the ventral side **(ventral fissure)**; (4) the outer layer **(white matter)**, largely composed of nerve fibers, and less compact than (5) the inner material of the cord **(gray matter)**, which contains (6) a large number of nerve cells. In the center of the gray matter is (7) the open canal **(central canal)**, which runs the entire length of the central nervous system. If the section happens to pass through a spinal nerve, the (8) **dorsal** and **ventral roots** may be seen, and it will be noted that they are continuous with the gray matter. Make a drawing of the section to show the structures as observed.

2. Using the high power, focus directly on the large, irregularly-shaped **motor nerve cells** in the ventral portion of the gray matter on either side of the cord. Note the large nuclei and the fibrillated cytoplasm. Try to find a nerve cell which has been sectioned so that it shows a long fiber **(axon)**. Draw one of the cells, showing all details of structure.

3. Secure a small piece of a fresh nerve taken from a chloroformed Frog, place it on a slide in a drop or two of normal salt solution and tear it apart with dissecting needles. Mount and examine under the microscope. Note that the nerve is composed of a number of fine, thread-like structures, or fibers, each of which consists of (1) a delicate, external membrane **(neurilemma)**; (2) a thick layer of fatty material **(medullary sheath)**, and (3) the central nerve fiber **(axon)** which, as noted above, is a direct continuation of the cytoplasm of the nerve cells. At intervals along each fiber, there are breaks **(Nodes of Ranvier)** in the medullary sheath, but the neurilemma and the axon are continuous. Draw to show the structure as observed.

EYE.

1. Place a dissecting microscope on its side in front of you and turn the mirror in such a position that you can examine your own eye. Make a drawing, showing (1) the **eyelids**; (2) the white of the eye **(sclerotic coat)**, which in front forms (3) the transparent **cornea**; (4) the underlying colored portion **(iris)**, with (5) a circular, central opening **(pupil)**.

2. Examine a Sheep's eye. Note: (1) the shape; (2) the character of the outer, protective covering **(sclerotic coat)**; (3) the attachment of the muscles, and (4) the optic nerve.

3. Examine an eye which has been cut in half and find the following structures: (1) the **sclerotic coat**, a comparatively thick layer of connective tissue, which, in the front of the eye, forms (2) the transparent **cornea**; (3) the **choroid coat**, a thin, deeply pigmented, vascular layer, which, in the front of the eye, forms (4) the colored **iris**, in the center of which is (5) the circular opening **(pupil)**; (6) the transparent **lens**, which lies just posterior to the iris, and (7) the sensory layer, or **retina**, which is directly continuous with (8) the **optic nerve**, running from the posterior part of the eye to the brain.

4. Note the following chambers of the eye: (1) the **anterior chamber**, situated between the cornea and iris; (2) the small **posterior chamber**, situated between the iris and lens and communicating with the anterior chamber through the pupil, and (3) the large chamber **(vitreous chamber)** posterior to the lens, in which the retina lies. The vitreous chamber is filled with a transparent, jelly-like material **(vitreous humor)**. The two chambers in front contain a more fluid substance **(aqueous humor)**.

5. Make a drawing, about three inches in diameter, showing the structures as observed.

HISTOLOGY OF MUSCLE TISSUE.

1. **Unstriated Muscle.** Examine, with the high power, a permanent preparation of a transverse section through the small intestine of a Frog. Focus directly on the unstriated muscle tissue, which consists of two layers: (1) an outer **longitudinal layer** lying just inside the thin, outer covering, or peritoneum, of the intestine, and (2) a thicker **circular layer.** A close examination of the latter shows that it consists of closely packed, elongated, spindle-shaped cells with definite nuclei and cell walls. The longitudinal layer shows this same type of tissue, but the cells there are cut transversely. Draw a small portion of each layer to show the structure of the cells.

2. **Striated Muscle.** Place a small piece of fresh muscle, from the leg of a Frog, in a drop of normal salt solution on a slide. Tear it thoroughly apart with dissecting needles. Add a drop of acetic carmine stain, mount and examine with the low and the high power. Note that this type of muscle tissue consists of long, striated, cylindrical bundles of fibers bound together by connective tissue **(perimysium).** Study the cytoplasm **(sarcoplasm)** of the muscle fibers and observe the distinct **transverse striations,** and the less distinct **longitudinal striations** which are present in it. Stained nuclei may also be found imbedded in the sarcoplasm. Draw to show the structure as observed.

3. Examine, with the high power, a permanent preparation of striated muscle tissue, the blood vessels of which have been injected with colored gelatine. Note the intimate relation existing between the capillaries and the striated muscle fibers. Draw to show the structure as observed.

HISTOLOGY OF CONNECTIVE TISSUE.

1. **Fibrous Connective Tissue.** Examine, with the high power, a permanent preparation of Frog skin. Note that: (1) the outer portion **(epidermis)** of the skin is made up of several layers of stratified epithelial cells; (2) the inner portion **(dermis)** of the skin is divided into a comparatively loose layer of connective tissue **(stratum spongiosum)**, which lies next to the epithelial cells, and consists of connective tissue fibers, in which are imbedded numerous glands, blood vessels, and lymph spaces. The other portion of the dermis consists of (3) a layer of very dense connective tissue **(stratum compactum)**, in which the bundles of wavy connective tissue fibers run, in general, parallel to the surface of the skin. At intervals this layer is crossed by vertical strands which extend through the stratum spongiosum to the epidermis. These strands are made up of connective tissue fibers and also, in some cases, muscle fibers, nerves, and blood vessels. Draw a portion of the section to show the structure as observed.

2. **Cartilage.** Examine, with the high power, a permanent preparation of hyaline cartilage from the sternum of a Frog. Note: (1) the transparent, homogeneous, intercellular substance **(matrix)** which possesses (2) numerous spaces **(lacunae)**, each of which contains (3) one or more nucleated **cartilage cells.** Note, also, in various regions of the preparation, that the lacunae containing the cartilage cells show a tendency to group together. Draw a portion of the section to show the structure as observed.

SKELETON OF THE DOG. (1).

A. Axial.

1. Examine a Dog's skull. .Note that it consists of the brain case, or **cranium,** and the **facial portion,** which forms the framework of the face and jaws. Locate the bony **sense capsules** which enclose and protect the nose, eyes, and ears. Observe the articulation of the lower jaw **(mandible),** at the posterior end of the skull, with the ventral surface of the posterior portion of the prominent **zygomatic arch.** Note the similarity and the relation of the teeth of both jaws and their adaptation for different purposes. Various openings **(foramina)** are present in the skull bones, which serve as exits for the cranial nerves and blood vessels. The largest of these is the **foramen magnum** at the posterior end of the skull, through which the spinal cord passes into the cranium. On each side of the foramen magnum is a smooth, rounded, prominence **(occipital condyle).** The condyles fit into depressions on the first vertebra of the spinal column, with which they articulate.

2. Examine the surface of the skull and note that it is composed of a considerable number of bones, which are jointed together by the irregular **sutures.** Identify the following bones: (1) the **occipitals,** which form the posterior part of the skull around the foramen magnum; (2) the **parietals,** which form a considerable portion of the dorsal and lateral walls of the cranium; (3) the **temporals,** in which the ears are located (consist chiefly of the dorsal **squamosal portions)** lie ventral to the parietals, and from each of them there is (4) a curved projection **(zygomatic process)** which unites anteriorly with (5) the **malar** bone to form the **zygomatic arch;** (6) the **frontals,** which lie anterior to parietals and dorsal to the eye; (7) the median **nasals,** which form the dorsal wall of the nose; (8) the **maxillae,** and (9) the small **premaxillae,** which together form the upper jaw and a large portion of the roof of the mouth; (10) the **palatines,** which lie in the roof of the mouth posterior to the maxillary bones; (11) the median **sphenoids,** posterior to the palatines, and (12) the **mandible,** or lower jaw.

3. Draw the skull from the left side, showing as many as possible of the features mentioned above.

4. Examine a **vertebra** from the thoracic, or lumbar, region of the spinal column. Note: (1) the large, solid **centrum,** with (2) the **neural arch** lying dorsal and containing (3) the **neural canal,** and (4) the **transverse processes** for the attachment of muscles, projecting laterally from each side; (5) the **neural spine,** which projects dorsally from the neural arch, and (6) the **anterior** and **posterior articular processes.** Draw the vertebra from either the end or the side.

SKELETON OF THE DOG (2).

B. Appendicular.

1. With the structural plan of the vertebrate pentadactyl limb clearly in mind, examine the mounted skeleton of a Dog and note the differences between the fore limbs and the hind limbs, together with their respective girdles.

2. Secure a detached fore limb and determine, from the mounted skeleton, whether it is a right, or left, limb. Identify the following bones: (1) the shoulder blade **(scapula)**, with **spinous process**; (2) the large **humerus**; (3) the **radius**, and (4) **ulna**—the latter is the larger and forms the main articulation with the humerus; (5) the wrist **(carpus)**, composed of seven **carpal** bones; (6) the hand **(manus)**, composed of five **metacarpal bones** and five **digits**. Each of the digits consists of three bones **(phalanges)** with the exception of the first, corresponding to our thumb, which has only two. Make a reduced drawing of the entire fore limb.

3. Secure a detached hind limb and determine from the mounted skeleton whether it is a right, or left, limb. Identify the following bones: (1) the **pelvis**, which has a bony attachment to the vertebral column; (2) the large **femur**; (3) **tibia** and (4) **fibula**—the former is the larger and forms the main articulation with the femur; (5) the ankle **(tarsus)**, composed of seven **tarsal** bones; the foot **(pes)** composed of five **metatarsal** bones, one of which is much reduced, and four digits—the first is lacking—each of which consists of three bones **(phalanges)**. Make a reduced drawing of the entire hind limb.

4. For comparison, study the limbs of a Bird, Bat, Horse and Man. Note, in all these types, the homologies of the principal bones, and the modification, consolidation, or suppression of certain of them to adopt the limb to its functional requirements.

SPERMATOGENESIS.

1. Examine, with the low and the high power, a permanent microscopic preparation of Mouse testis. Note that it consists of a great number of tubules **(seminiferous tubules)** in the walls of which the male germinal cells **(sperm)** develop. The tubules are greatly convoluted, and, consequently, in the preparation, they are sectioned at various angles. At one side of the testis is a section through the coiled **epididymis**, which constitutes a portion of the conducting tube which carries the mature sperm from the testis to the exterior. Draw the entire testis in outline and fill in a portion with careful detail.

2. Select a seminiferous tubule which has been sectioned approximately transversely and study with the high power. Note the arrangement, size, and structure of the **spermatogonia, spematocytes, spermatids,** and mature **sperm.** Draw the entire tubule in outline and fill in a portion, showing, with careful detail, the germinal cells in various stages of maturation.

3. Examine the epididymis under high power. Note that the tubules are filled with mature sperm. Draw a tubule to show the structure as observed.

OÖGENESIS.

1. Examine a fresh ovary of a Pig and note the numerous more or less transparent prominences **(Graafian follicles)**, of various sizes, in which the female germinal cells **(eggs)** develop. The more mature follicles are larger and more transparent. Note also the hard, yellowish swellings **(corpora lutea)** into which a follicle is transformed after the mature egg has been discharged. Make an enlarged drawing of the entire ovary to show the structure as observed.

2. Examine, with the low power, a permanent preparation of Mouse ovary. Note the outer covering **(germinal epithelium)** in which the eggs are first found, and from which they move into the body of the ovary, where they become surrounded by follicle cells, thus forming the **Graafian follicles.** The latter can be seen in various stages of development. In the immature follicles the large, central egg is closely surrounded by several layers of the follicle cells. In the larger, more mature follicles, a liquid-filled cavity develops around the egg. In close contact to the egg are a few layers of the follicle cells, which also support it at one point. Areas of the yellowish **corpora lutea** can also be seen in the preparation. The ground substance of the ovary consists of connective tissue with numerous cells and blood vessels imbedded in it. Draw the entire ovary in outline and fill in a portion to show the structure as observed.

3. Select the most mature follicle, containing an egg with nucleus, which your preparation shows. Study it carefully with the high power and draw the entire follicle in detail.

CELL DIVISION (MITOSIS).

1. Examine, with the low and the high power, a permanent preparation of a transverse section of the uterus of Ascaris. Note the thick, cellular uterine wall and the central cavity, containing many thick-shelled eggs, which are in various stages of mitosis. Draw the entire section of the uterus in outline and then fill in a sector with careful detail.

2. Study the preparation with the high power. Identify eggs in the following stages of mitosis and make a drawing (two inches in diameter) of each stage:

I. **Contact** of the male and female **pronuclei.**

II. **Early prophase,** with the chromatin in each pronucleus in the form of a long thread **(spireme),** and the centrosomes at opposite poles of the fusion nucleus **(synkaryon).**

III. **Late prophase,** with the chromatin in the form of definite **chromosomes,** the nuclear membranes broken down, and the **spindle** well developed.

IV. **Metaphase,** with the chromosomes divided in the equatorial plate; or **Anaphase,** with the chromosomes moving along the spindle fibers toward the centrosomes.

V. **Telophase,** with the spindle breaking down and the cytoplasm of the cell constricting to form two cells.

Label in each of the above stages where present: **egg shell, cytoplasm, centrosomes, asters, spindle fibers, and chromatin, or chromosomes.**

DEVELOPMENT OF THE FROG (1).

1. Place an unsegmented Frog's egg in a watch glass containing water and examine it, both with the dissecting microscope and with the low power of the compound microscope. Note that the egg is enclosed in a transparent jelly and that it consists of a dark-colored portion **(animal pole)**, which tends to lie uppermost in the water, and a lighter-colored portion **(vegetal pole)**. Make a drawing of the egg from the side, one inch in diameter, so as to show both poles and the jelly.

2. Examine, in the same way, the following segmentation stages of Frog's eggs: 2-4 cells, 8 cells, 20-30 cells, and many cells, or **blastula.** Note in each stage the direction of the cleavage planes and comparative size of the cells in the animal and vegetal poles. Make a drawing of each stage from the side as above, omitting the jelly.

3. Examine, as before, a Frog's egg in which the growth of the dark cells of the animal pole over the light cells of the vegetal pole has begun **(gastrula).** As this process of gastrulation continues, the circular area **(blastopore)** at the vegetal pole becomes smaller. Finally, when gastrulation is complete, the blastopore is very small, and only a tiny portion of the cells of the vegetal pole is visible externally, and this region is known as the **yolk plug.** Draw the gastrula from the vegetal pole, showing the yolk plug.

DEVELOPMENT OF THE FROG (2).

4. Examine, in a watch glass of water, as before, a later stage in the development of the Frog in which the body of the animal has begun to elongate in an anteroposterior direction. Note: (1) the blastopore, which was circular, has now become a slit-like opening marking the posterior end of the embryo, and (2) the dorsal, longitudinal groove **(neural groove)**, which indicates the position of the future central nervous system. Draw the embryo from the posterior end.

5. Examine, as before, still later developmental stages as follows: (1) an embryo in which the head and tail have just become differentiated; (2) an embryo with well-developed, external gills; (3) a fully-formed, free-swimming tadpole, in which the external gills have become covered by the **operculum**, leaving only a small opening **(spiracle)** on the left side of the animal in the gill region; (4) an embryo in an early stage of metamorphosis, showing a single, small pair of hind legs, and (5) an embryo in a late stage of metamorphosis, with both pairs of legs present, and the tail in process of absorption. Draw each of these embryos from the left side and label in each stage, where developed; nose, eye, mouth, sucker, gills, operculum, muscle plates, blastopore or anus, and tail fin.

DEVELOPMENT OF THE CHICK (1).

1. Examine, with the dissecting microscope and with the low power of the compound microscope, a permanent mount of a three-day Chick embryo. Note that the general shape resembles a "reversed question-mark" with the head end turned toward the right. Anteriorly, the embryo is lying on its left side and posteriorly on its ventral surface. On each side of the embryo, note the vascular area with the large vessels (**vitelline arteries**, and **veins**), which enter the embryo near the middle of the body.

2. Beginning at the posterior end of the body, identify the median spinal cord, and on each side of it the segmental, paired, muscle plates (**myotomes**). Ascertain the number in your specimen. Find the **amnion** (one of the foetal membranes) which later completely encloses the embryo, and at this stage ends somewhat posterior to the region where the vitelline vessels enter the embryo.

3. Study the anterior end of the embryo and locate: (1) the **fore-brain**, with the rudiments of the **eye** and **nose**; (2) the large, rather spherical **mid-brain**, and, to the left, (3) the smaller **hind-brain**, with a large, dorsal depression (**fourth ventricle**). (4) The rudiment of the **ear** is situated near the posterior end of the hind-brain, and appears as a small, flask-shaped vesicle. (5) The twisted, S-shaped **heart** lies outside the body wall in the space between the tip of the head and the curved portion of the trunk. It consists at this stage of (6) a large posterior **ventricle**, into which (7) the **auricle** opens. A portion of the auricle can be seen to the left. To the right, and leading from the ventricle, is (8) the **conus arteriosus**, and it soon divides to form a number of **branchial vessels** which run dorsally between (9) the **gill slits** and form a portion of the aortic arches.

4. Make a full page drawing of the entire embryo to show the structures as observed.

DEVELOPMENT OF THE CHICK (2).

1. Place an egg, which has been incubated three days, in a finger-bowl of warm (about 38° C), normal salt solution, with the blunt end pointing to your right. Hold the egg firmly with one hand, and, with the other, carefully insert the point of the scissors in the center of the blunt end. While holding the egg in the same position continue the cut entirely around the egg a little **below** the equator, and then lift off the upper portion of the shell, leaving the rest of the egg, including the lower portion of the shell, with the embryo, immersed in the salt solution.

2. Examine, with the dissecting microscope, the translucent embryo lying on the yolk in the center of the **vascular area**, noting how it is placed with reference to the long axis of the egg. Note the beating **heart**, the **vitelline arteries** and **veins**, which pass out to the side from the middle of the embryo, and the anterior **vitelline vein**, which runs under the anterior portion of the embryo. Determine the **pulse rate.** Make a drawing of the entire specimen, with the embryo *in situ,* to show the general arrangement.

3. Carefully make a circular cut, with small scissors, through the yolk membrane **(cell membrane)**, just outside the limit of the vascular area. With fine forceps take hold of an edge of the vascular area and very gently separate it, with the attached embryo, from the underlying yolk. Hold the detached portion with the forceps, below the surface of the liquid, and with the other hand immerse a watch glass in the liquid. Then gently float the embryo into the watch glass, keeping it at all times below the surface of the liquid. Gently raise the watch glass and remove it, with the embryo floating in it, entirely from the finger-bowl, taking great care not to lose the embryo. With a pipet draw off a considerable portion of the fluid around the embryo, and replace it with a fresh supply of warm salt solution.

4. Examine the embryo with the dissecting microscope, and identify the structures which you previously noted in the permanent preparation of the three-day chick embryo. Under the low power of the compound microscope observe the movement of the corpuscles in the blood vessels.

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